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**Pre-Main Sequence Stars in the Chamaeleon Cloud and  
Pre-Main Sequence Stars in the Rho Ophiuchi Cloud Core**

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This grant funds two closely related studies of young stars under the ROSAT Guest Observer Program. Each project resulted in one major study, reported at various conferences and published (or submitted for publication) in the *Astrophysical Journal*. The grant funds have been expended.

First, a major paper on ROSAT discovery of X-ray emitting young stars in the Chamaeleon star forming cloud was published in the *Astrophysical Journal*, with summaries at several conferences. Authors are the PI, Sophie Casanova (a doctoral student of the Universite de Paris studying under Dr. Montmerle), Co-I Thierry Montmerle, and Dr. Jean Guibert of the Observatoire de Paris who led the optical identification effort.

Two soft X-ray images of the Chamaeleon I star forming cloud obtained with the *ROSAT* Position Sensitive Proportional Counter are presented. Seventy reliable, and 19 possible additional, X-ray sources are found. Eighty percent of these sources are certainly or probably identified with T Tauri stars formed in the cloud. Nineteen to 39 are proposed new “weak” T Tauri (WTT) stars which will significantly enlarge the known cloud population. Individual T Tauri X-ray luminosities range from  $\sim 6 \times 10^{28}$  to  $\sim 2 \times 10^{31}$  erg s $^{-1}$  (0.4–2.5 keV), or  $\sim 10^2 - 10^4$  times solar levels. The *ROSAT* images are an order of magnitude more sensitive, with 3-4 times more stellar identifications, than earlier *Einstein Observatory* images of the cloud. The PI organized a collaboration with David Huenemoerder (MIT) and Warrick Lawson (Australian Defence Force Academy) to obtain optical spectroscopic confirmation of the ROSAT-discovered stars. Most are confirmed to be new WTT stars.

A wide range of issues is addressed by these data. The spatial distribution and Hertzsprung-Russell diagram locations of the stars indicate that WTT stars and “classical” T Tauri (CTT) stars are coeval. Their X-ray luminosity functions are also essentially identical, suggesting that CTT stars have the same surface magnetic activity as WTT stars. The X-ray luminosities of well-studied Chamaeleon I cloud members are strongly correlated with a complex of four stellar properties: bolometric luminosity, mass, radius and effective temperature. The first relation can be expressed by the simple statement that low mass Chamaeleon I stars have  $L_x/L_\star = 1.6 \times 10^{-4}$ , within a factor of  $\pm 2$  ( $1 \sigma$ ) and the last relation by  $F_x \propto R_\star$ . There is thus no evidence of magnetic saturation of the stellar surfaces. We find no evidence for the absorption of soft X-rays in CTT winds and/or boundary layers traced by the strength of the H $\alpha$  emission. The mean X-ray luminosity for an unbiased optically selected T Tauri sample is  $1.6 \times 10^{29}$  erg s $^{-1}$ , and we find evidence for temporal evolution of X-ray emission for stars within the pre-main sequence evolutionary phase. The total pre-main sequence population ( $M_\star > 0.1 M_\odot$ ) of the cloud is estimated to be  $\geq 200$  stars, with X-ray emitting WTT stars outnumbering CTT stars 2:1–3:1. The inferred star formation efficiency for the cloud cores is  $\geq 20\%$ .

Second, a study of X-ray emitting stars in a deep ROSAT image of the  $\rho$  Ophiuchi star forming cloud cores has been completed, and is being submitted for publication in the *Astrophysical Journal*. A list of X-ray sources, fluxes, signal-to-noise ratios and boresight-corrected positions has been compiled, and optical identification down to 22 $^m$  are obtained. Of the 55 reliable ROSAT sources, virtually all are associated with embedded infrared-detected T

Tauri stars. Four are tentatively identified with infrared Class I sources; i.e. protostars still enveloped in their accreting envelope. The findings imply that X-ray emission extends, without much change, to the earliest stages of star formation. The study discusses in detail implications of the many X-ray sources embedded deep in molecular clouds including ionization of the circumstellar disks and outflows, partial ionization of the widespread molecular gas, and sputtering of interstellar dust grains. T Tauri X-rays may provide a crucial link in the photoionization self-regulation of star formation in the galaxy.

## References

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